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Bantz et al.

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(54) **MINIATURIZED SYRINGE PUMP SYSTEM AND MODULES**

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(73) Assignee: **Parker-Hannifin Corporation**, Cleveland, OH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 678 days.

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(51) **Int. Cl.**
F04B 17/03 (2006.01)
A61M 5/145 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***F04B 17/03*** (2013.01); ***A61M 5/1452*** (2013.01); ***A61M 5/1456*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC A61M 5/1452; A61M 5/1456; B01L 3/0217; F04B 17/03; F04B 19/006; G01N 35/1072
See application file for complete search history.

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Primary Examiner — Jill Warden
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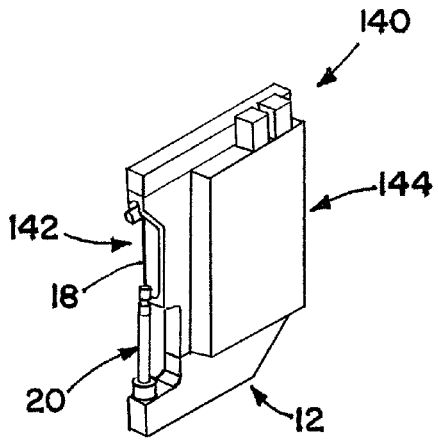
(57) **ABSTRACT**

Provided is a liquid handling device for use in a liquid handling system including a plurality of the liquid handling devices assembled in side-by-side relationship at a center-to-center spacing of X. The device includes a barrel, plunger, motive device and electronics assembled together in an envelope having a front portion including at least the barrel and plunger, and a rear portion including at least a portion of the electronics. The rear portion has a thickness greater than X but no greater than 2X, and the front portion has a thickness no greater than X and is laterally offset relative to a center plane of the envelope, whereby the liquid handling device can be assembled with another reversely oriented liquid handling device at a center-to-center spacing of X and a total combined width no greater than 2X.

20 Claims, 14 Drawing Sheets



(51) **Int. Cl.**

B01L 3/02	(2006.01)
F04B 19/00	(2006.01)
G01N 35/10	(2006.01)
G01N 35/00	(2006.01)

(52) **U.S. Cl.**

CPC ***B01L 3/0217*** (2013.01); ***F04B 19/006*** (2013.01); ***G01N 35/1072*** (2013.01); *B01L 2200/028* (2013.01); *B01L 2300/0861* (2013.01); *G01N 2035/00326* (2013.01)

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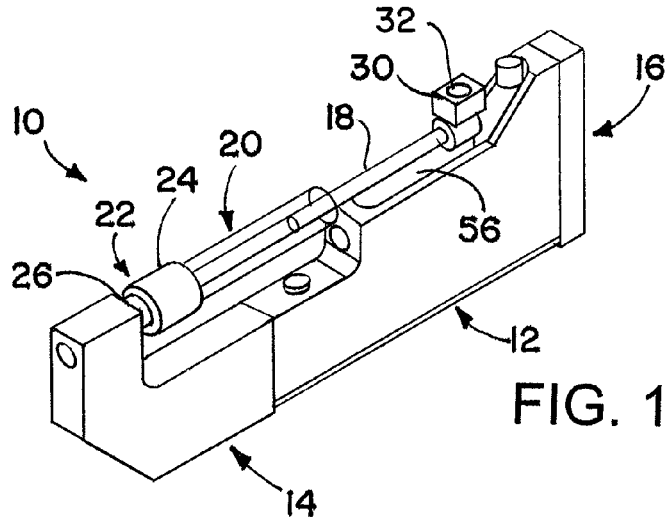


FIG. 1

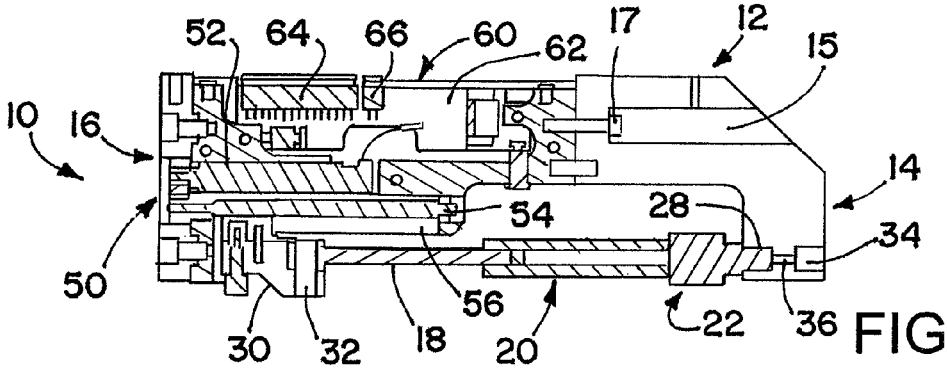


FIG. 2

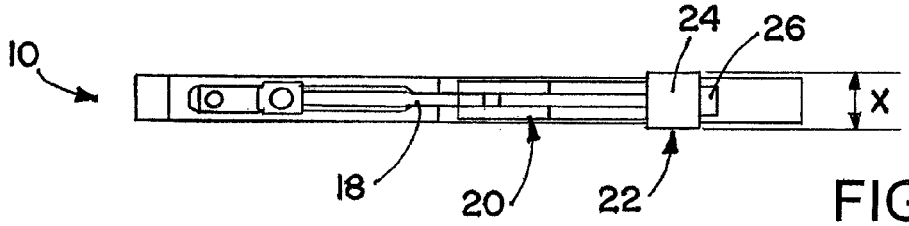


FIG. 3

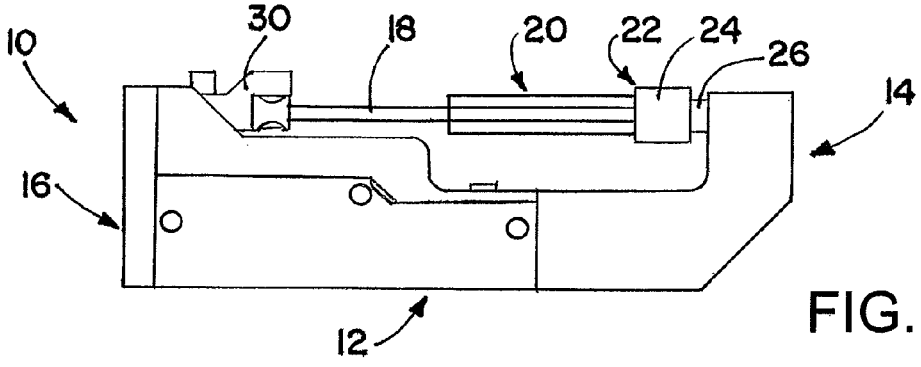


FIG. 4

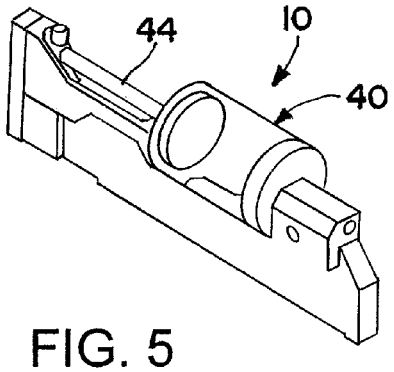
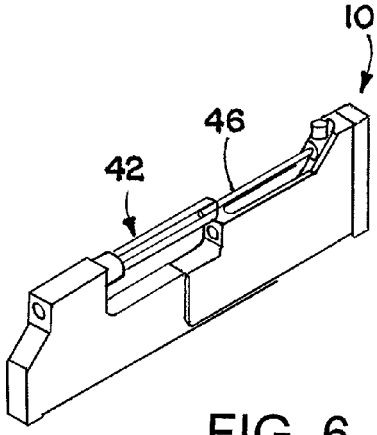


FIG. 5



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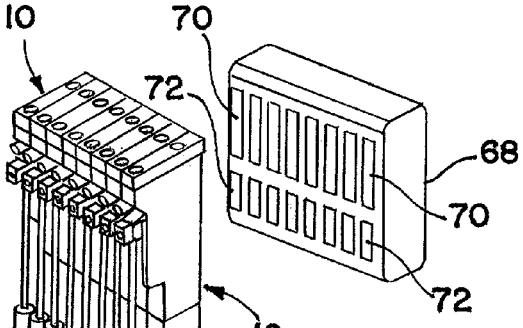

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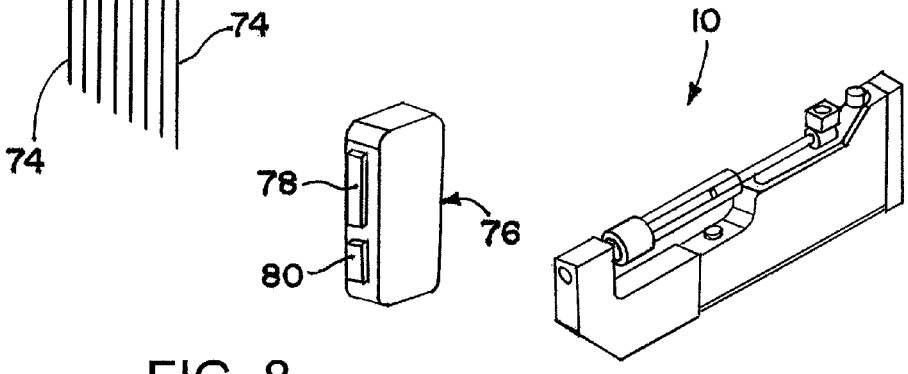

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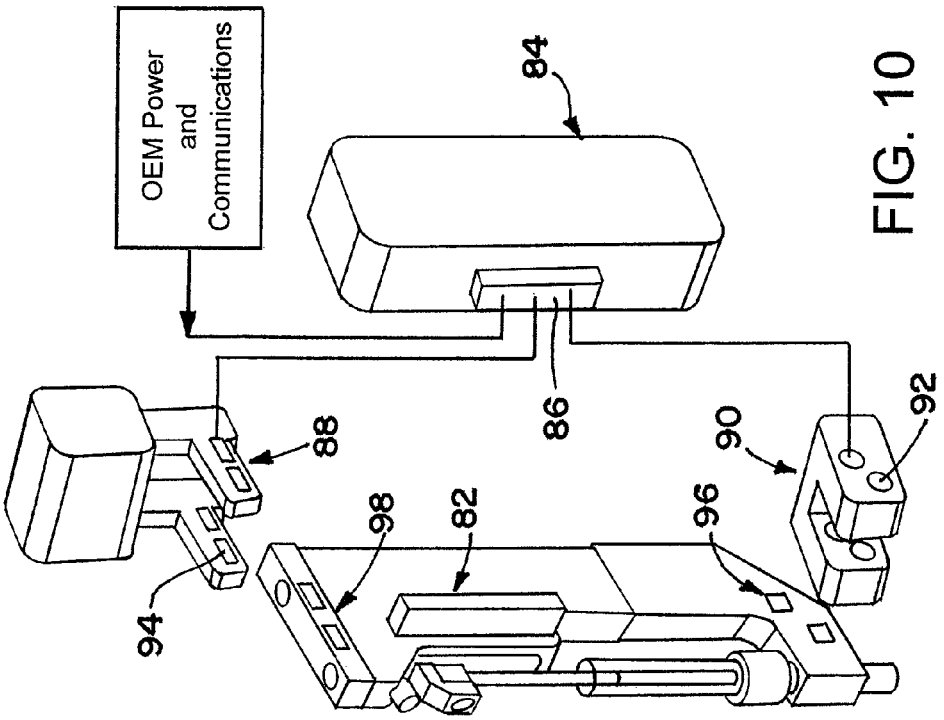
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FIG. 10

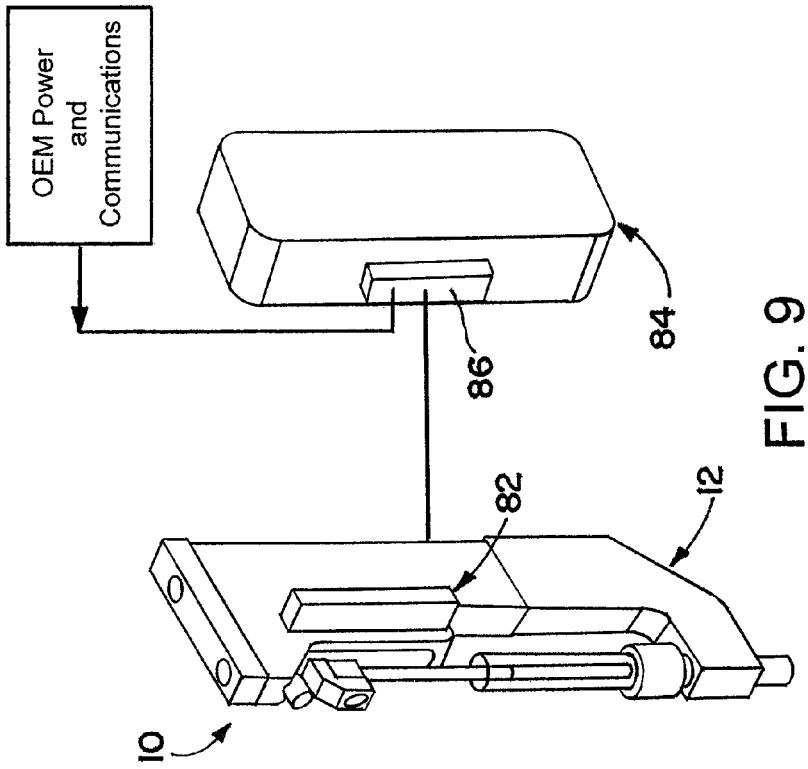
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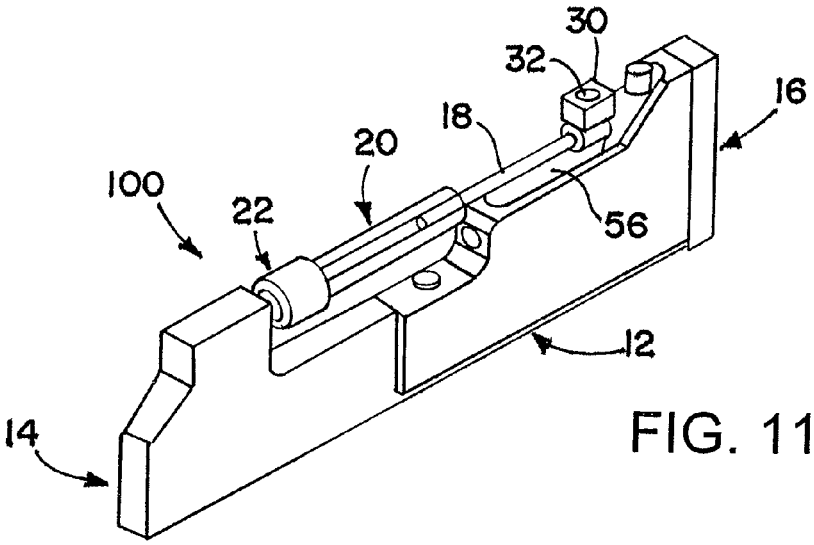
FIG. 9



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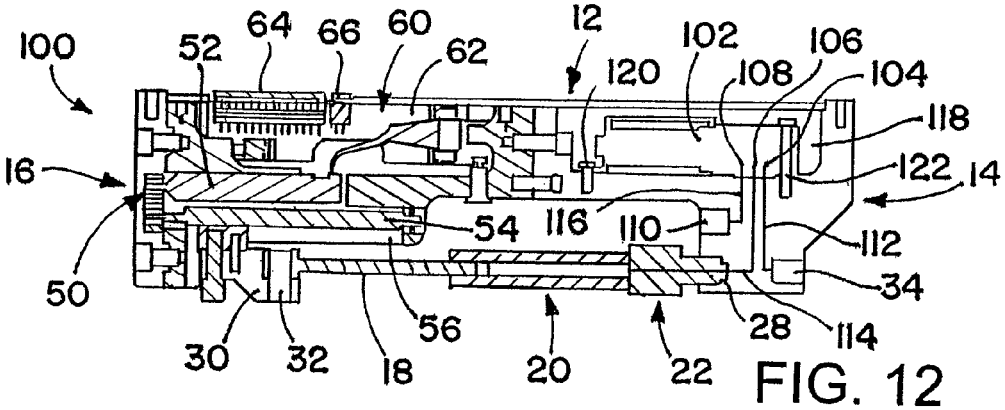
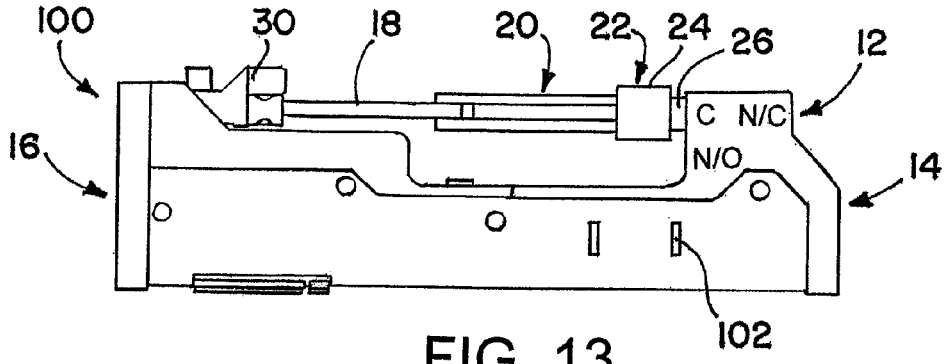


FIG. 12



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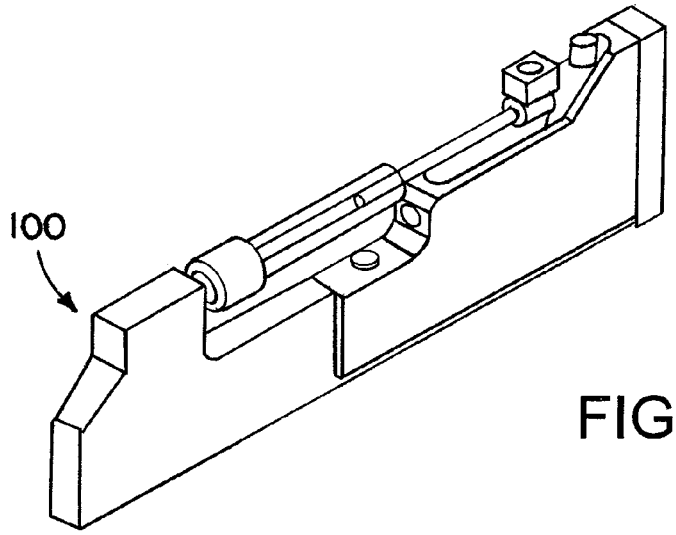

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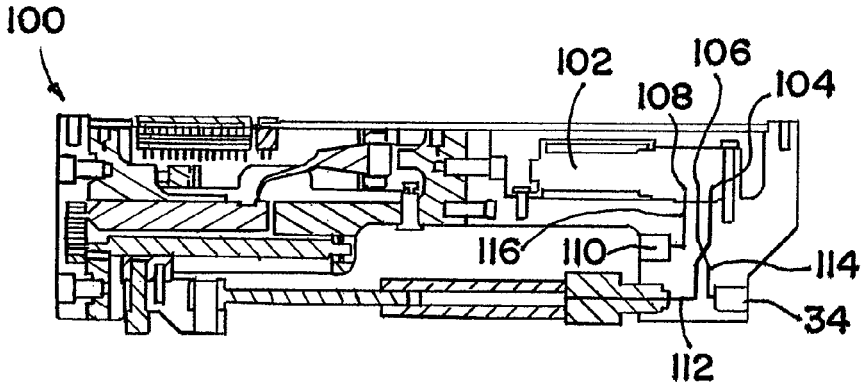

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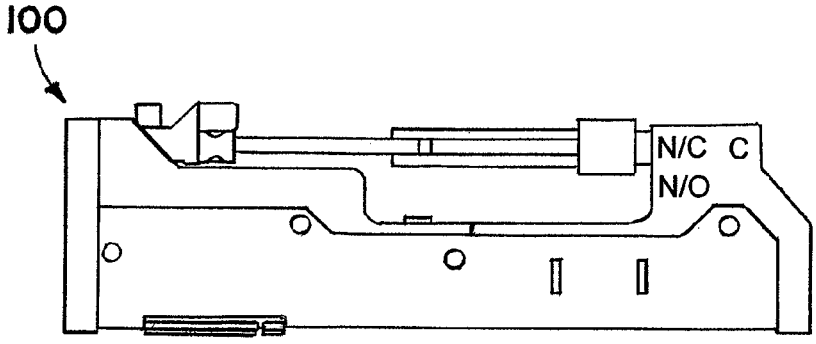
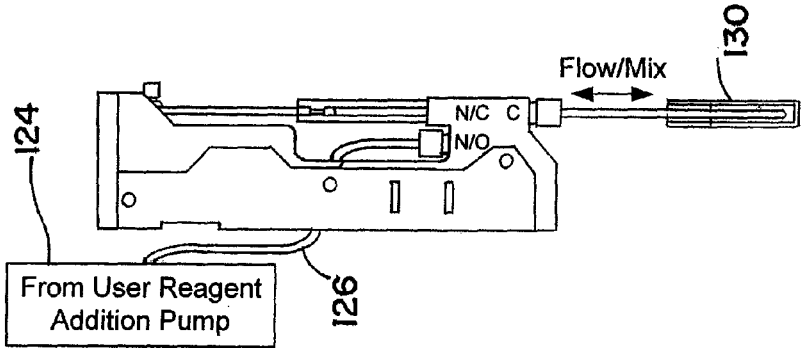


FIG. 16



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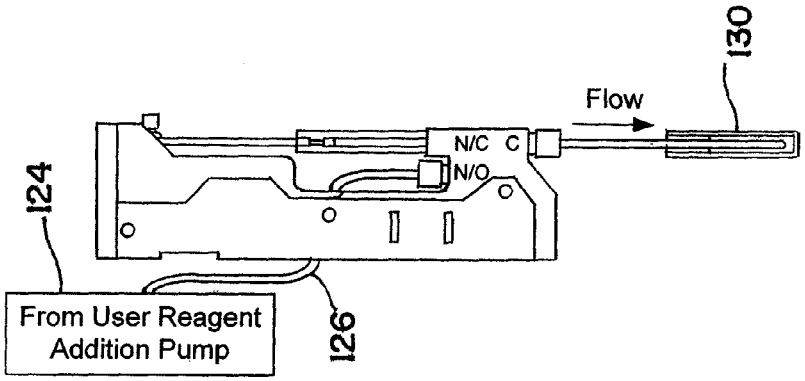

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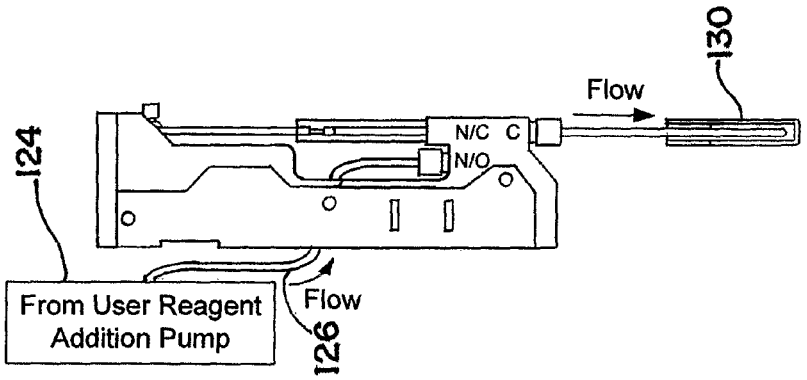

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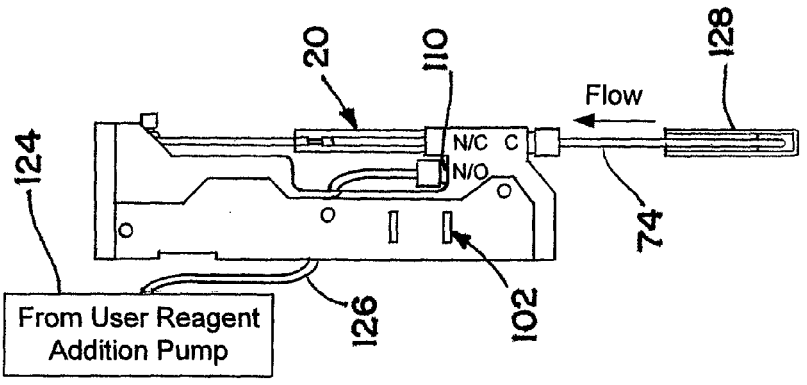

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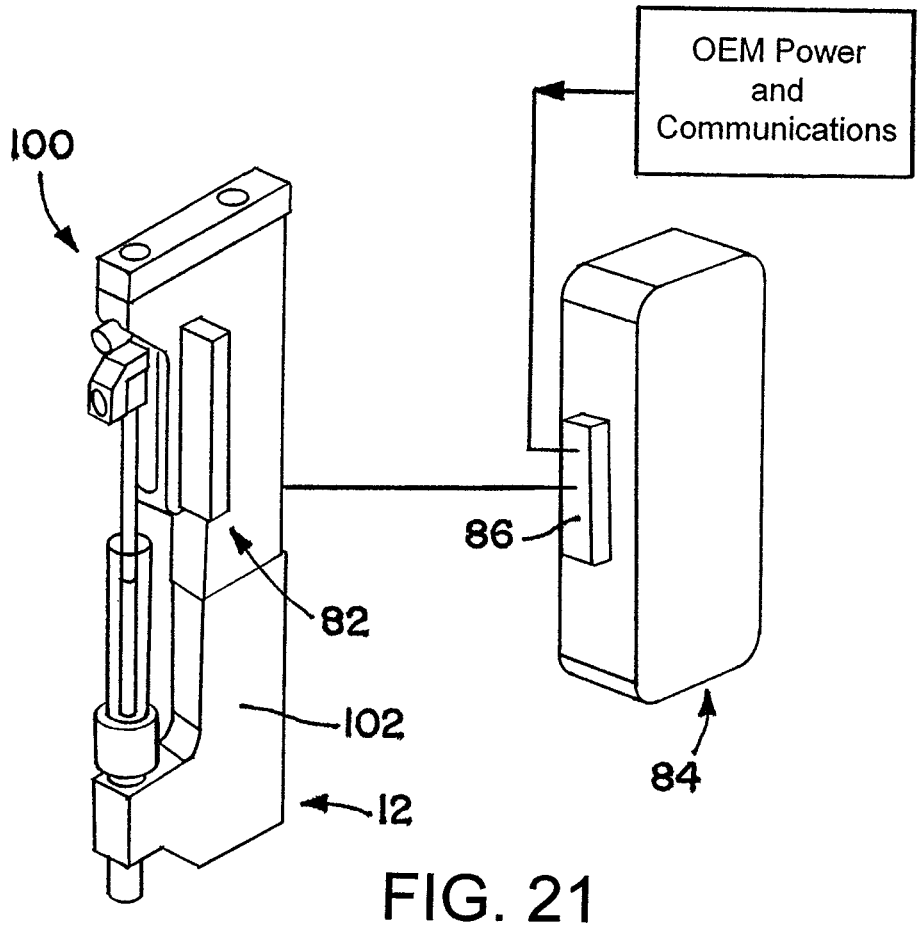

FIG. 21

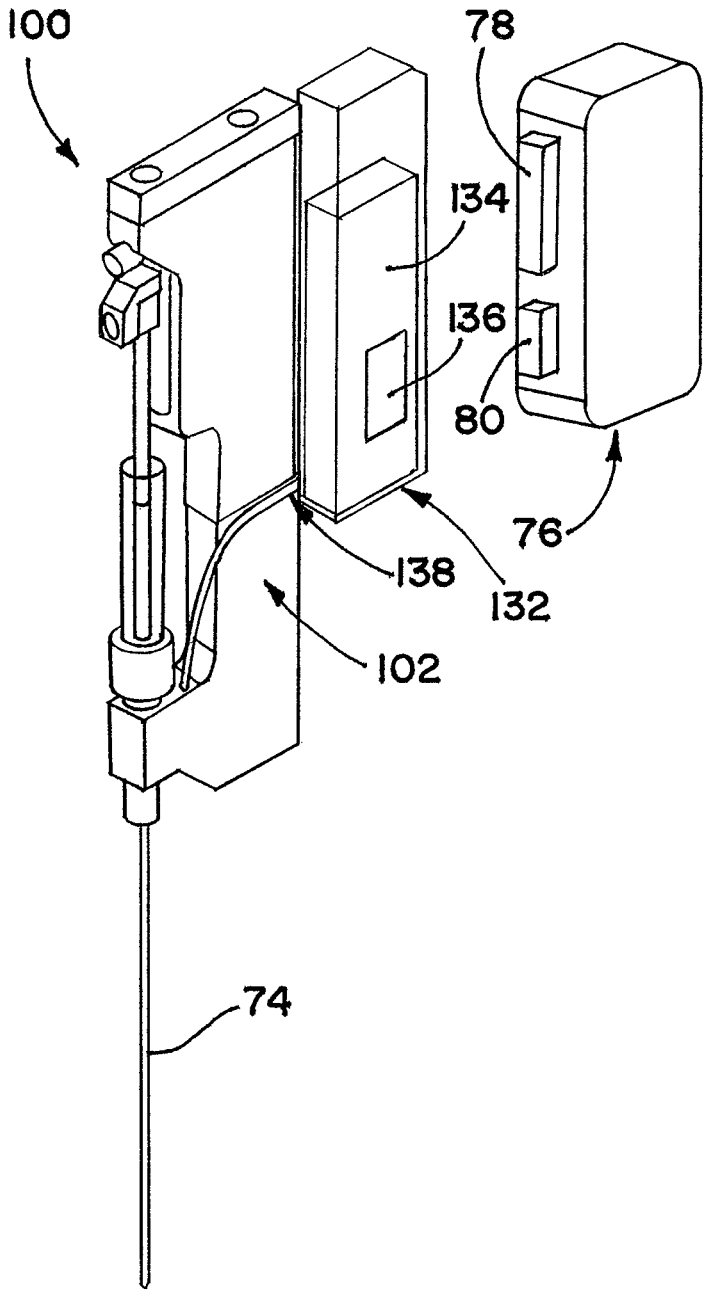

FIG. 22

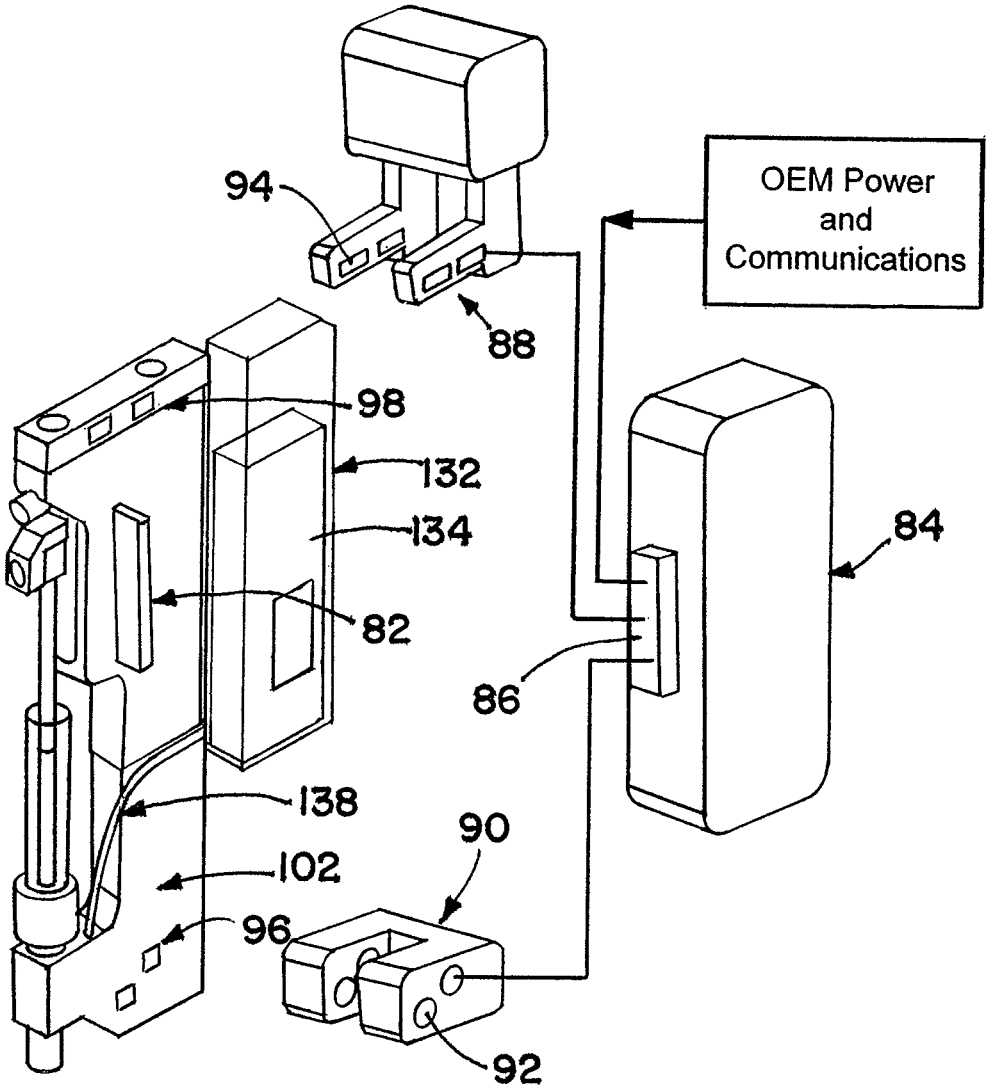
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FIG. 23

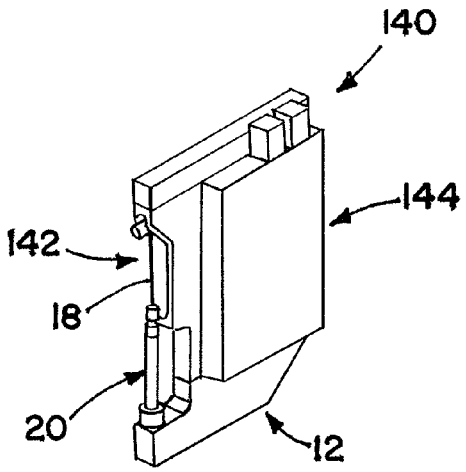


FIG. 24

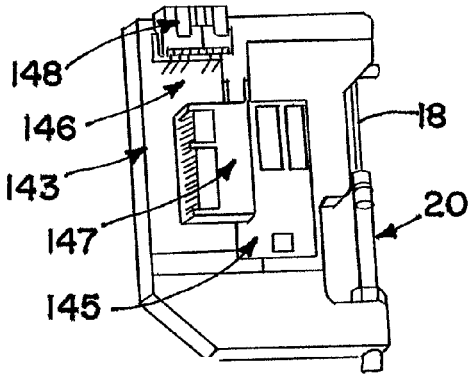


FIG. 25

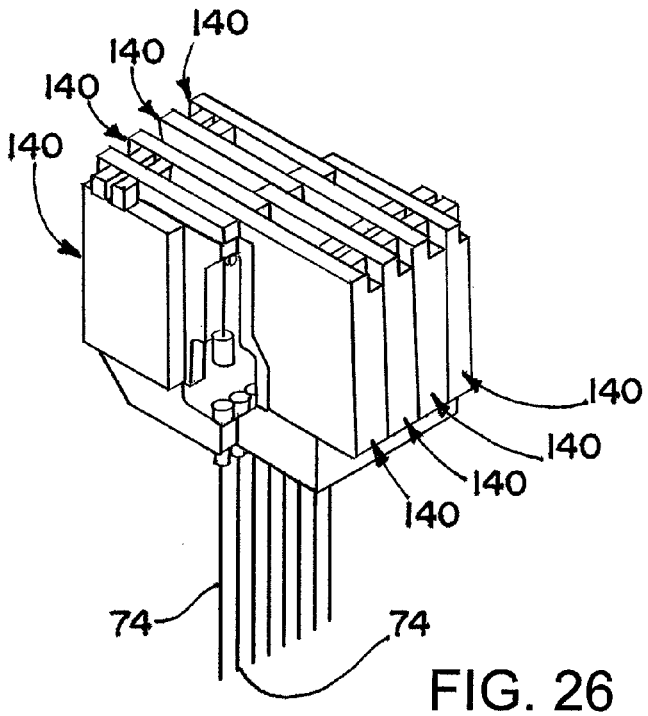


FIG. 26

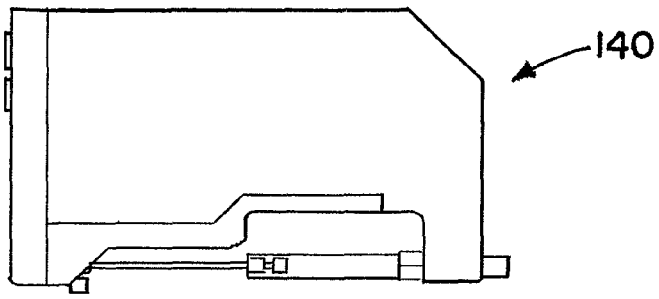


FIG. 27

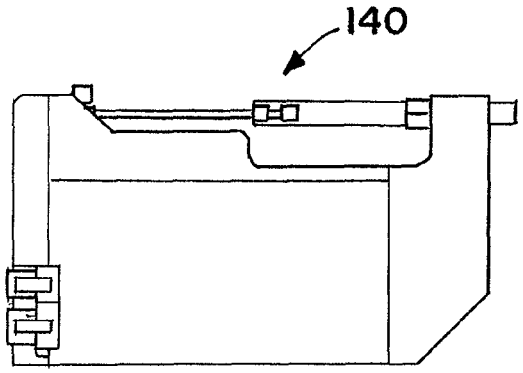


FIG. 28

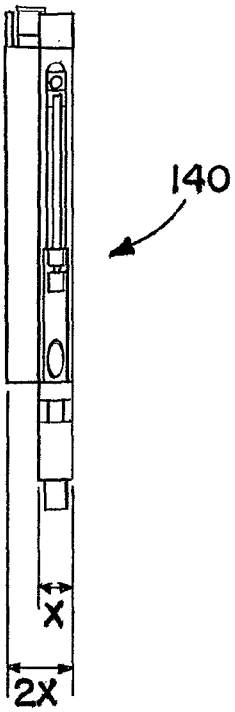


FIG. 29

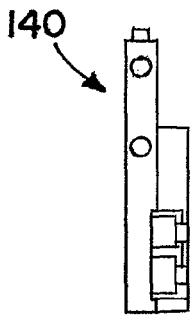


FIG. 30

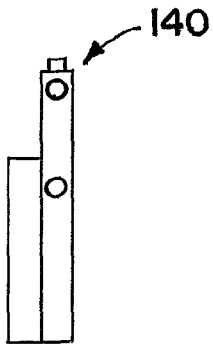


FIG. 31

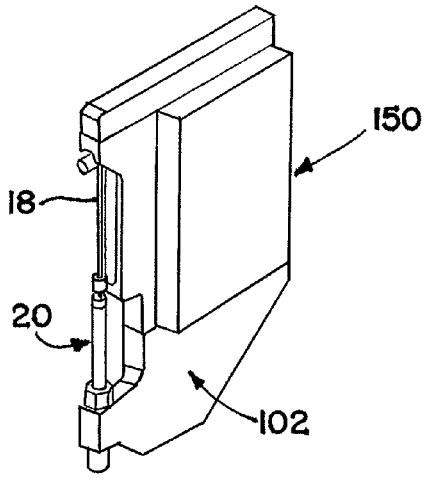
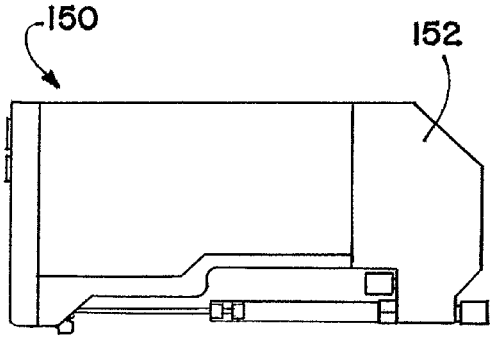


FIG. 32



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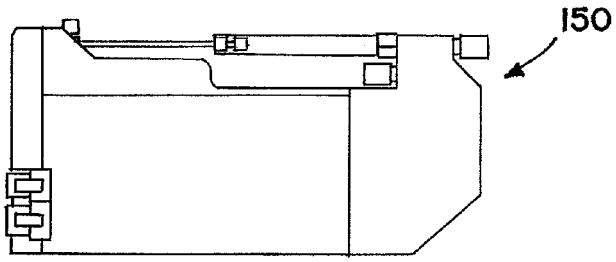

FIG. 34

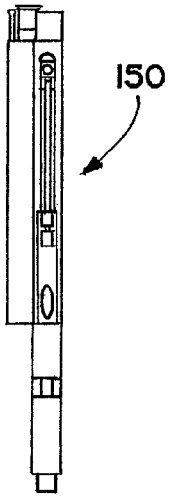

FIG. 35

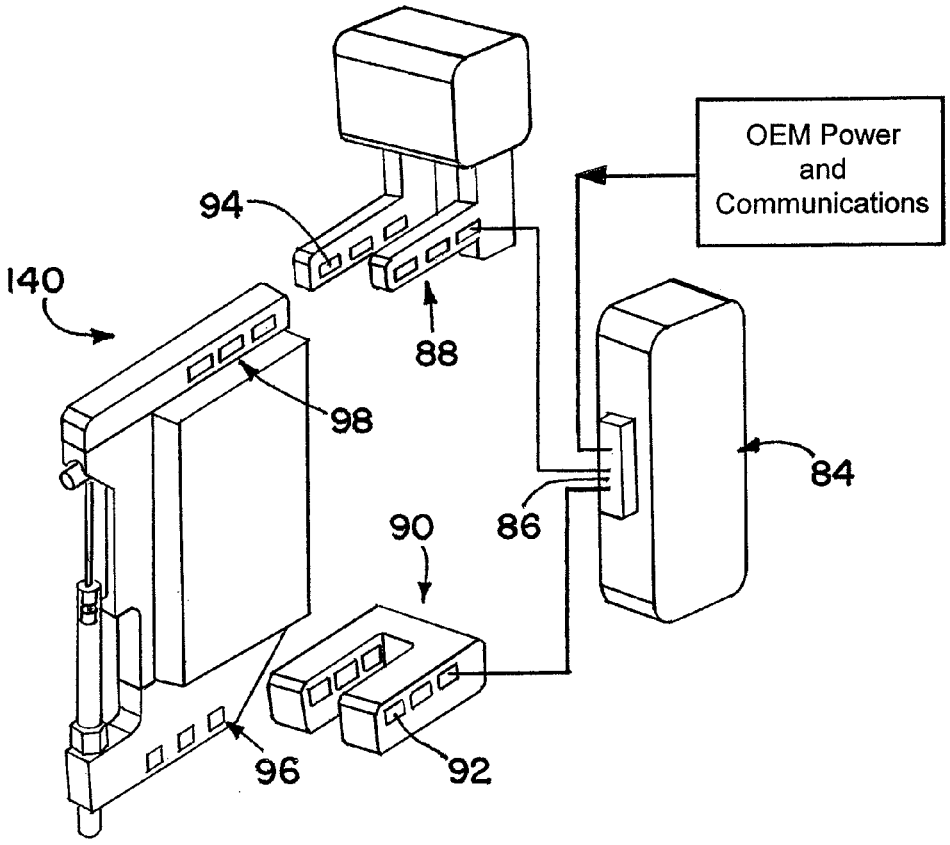

FIG. 36

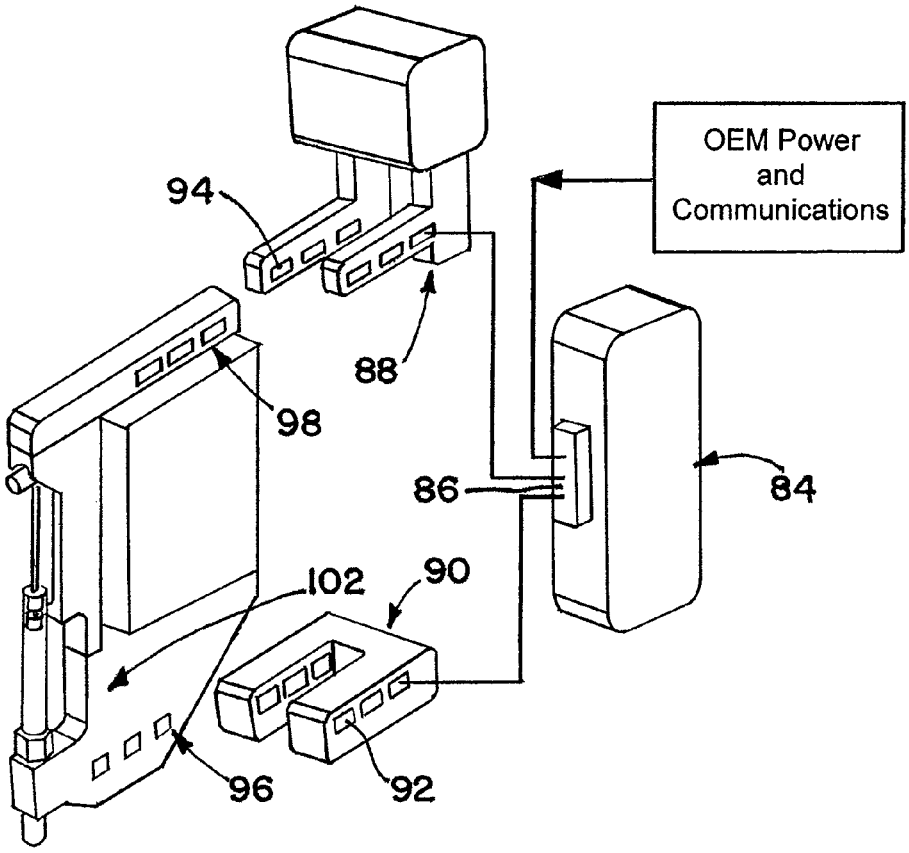

FIG. 37

MINIATURIZED SYRINGE PUMP SYSTEM AND MODULES

RELATED APPLICATION

This application is a national phase of International Application No. PCT/US2011/039264 filed Jun. 6, 2011 and published in the English language, which claims the benefit of U.S. Provisional Application No. 61/351,550 filed Jun. 4, 2010.

FIELD OF THE INVENTION

The invention herein described relates generally liquid handling devices and systems having particular application in laboratory sample management systems for analytical applications, and more particularly to a miniaturized syringe pump and pump system useful for manipulation and transfer of reagents and samples in conjunction with micro-titration plates having spaced sample wells in a grid.

BACKGROUND

Liquid handling devices heretofore have been used to provide for aspirating and/or dispensing an agent. These devices include syringe pumps that are typically located remotely from the sample wells due to typical syringe pump form factor. This presents various challenges for basic liquid handing. Remote pumps require long tube lengths, which extend through robotic system cable/fluidic management systems. This causes fundamental fluid handling issues regarding liquid dispense precision, accuracy and long term reliability.

SUMMARY OF THE INVENTION

The present invention provides various improvements in liquid handling devices and particularly syringe pumps that no longer need to be located remotely from the sample wells.

According to one aspect of the invention, a liquid handling device, in particular a syringe pump, is provided for use in a liquid handling system and includes a plurality of the liquid handling devices assembled in side-by-side relationship at a center-to-center spacing of X. The device includes a barrel, a plunger movable in the barrel for dispensing or aspirating liquid from or into the barrel, an electrically powered motive device for moving the plunger in the barrel for dispensing or aspirating liquid from or into the barrel, and electronics for controlling the motor and for communicating with an external component. The barrel, plunger, motive device and electronics are assembled together in an envelope having a front portion including at least the barrel and plunger, and a rear portion including at least a portion of the electronics. The rear portion has a thickness greater than X but no greater than 2X, and the front portion has a thickness no greater than X and is laterally offset relative to a center plane of the envelope, whereby the liquid handling device can be assembled with another reversely oriented liquid handling device at a center-to-center spacing of X and a total combined width no greater than 2X.

The liquid handling device can include a valve contained within the envelope, wherein the electronics control operation of the valve. The valve may include a first port connected to a dispensing/aspirating lumen, in particular a syringe needle, a second port connected to the barrel, and a third port connected to an inlet that provides for connection of the liquid handling device to a source of or reservoir for a liquid.

According to another aspect of the invention, a liquid handling device is provided for use in a liquid handling system including a plurality of the liquid handling devices assembled in side-by-side relationship at a center-to-center spacing of X. The device includes a barrel, a dispensing/aspirating lumen, a plunger movable in the barrel for dispensing or aspirating liquid from or into the barrel, an electrically powered motive device for moving the plunger in the barrel for dispensing or aspirating liquid from or into the barrel, a valve having a first port connected to the dispensing/aspirating lumen, in particular a syringe needle, a second port connected to the barrel, and a third port connected to an inlet that provides for connection of the liquid handling device to a source of or reservoir for a liquid, and electronics for controlling the motor and valve.

The plunger, motive device, valve and electronics are assembled together in an envelope having a thickness no greater than X.

The liquid handling device may also include a plurality of liquid handling devices assembled at a center-to-center spacing of X.

According to still another aspect of the invention, a liquid handling device is provided for use in a liquid handling system that includes a housing having spaced apart first and second end portions defining therebetween an opening for receiving a barrel and a plunger reciprocally movable in the barrel. The barrel is removably attachable to the first end portion and the plunger is pivotally attachable to a linearly movable carriage, whereby upon separation of the barrel from the first end, the barrel is rotated out of a plane of the liquid handling device for placement of a different barrel.

The liquid handling device may include a valve having a first port connected to a dispensing/aspirating lumen, in particular a syringe needle, a second port connected to the barrel, and a third port connected to an inlet that provides for connection of the liquid handling device to a source of or reservoir for a liquid. Alternatively, the first port may be connected to the barrel and the second port is connected to the dispensing/aspirating lumen, in particular the syringe needle.

The liquid handling device may have a thickness no greater than X. The liquid handling device may also include a plurality of liquid handling devices assembled at a center-to-center spacing of X.

According to yet another aspect of the invention, a liquid handling device for use in a liquid handling system includes a housing having spaced apart first and second end portions defining therebetween an opening for receiving a barrel, a dispensing/aspirating lumen, a plunger movable in the barrel for dispensing or aspirating liquid from or into the barrel, and an electrically powered motive device for moving the plunger in the barrel for dispensing or aspirating liquid from or into the barrel, and an electronics module removably mounted to the housing.

Further features of the invention will become apparent from the following detailed description when considered in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view an exemplary liquid handling device in accordance with the invention;

FIG. **2** is a side cross-sectional view of the liquid handling device of FIG. **1**;

FIG. **3** is a front view of the liquid handling device of FIG. **1**;

FIG. **4** is a side view of the liquid handling device of FIG. **1**;

FIG. **5** is a perspective view of the liquid handling device of FIG. **1** including a replacement barrel;

FIG. **6** is a perspective view of the liquid handling device of FIG. **1** including a replacement having a barrel with a diameter smaller than the barrel of FIG. **5**;

FIG. **7** is a perspective view of a bank of liquid handling devices coupled together and configured to mate with an electronic control module;

FIG. **8** is a perspective view of the liquid handling device configured to mate with an electronic control module;

FIG. **9** is a perspective view of the liquid handling device configured to mate with a communication module;

FIG. **10** is a perspective view of the liquid handling device configured to mate with the communication module and communicate with a gripper and/or a docking station;

FIG. **11** is a perspective view of another exemplary liquid handling device in accordance with the invention;

FIG. **12** is a side cross-sectional view of the liquid handling device of FIG. **11**;

FIG. **13** is a side view of the liquid handling device of FIG. **11**;

FIG. **14** is a perspective view of yet another exemplary liquid handling device in accordance with the invention;

FIG. **15** is a side cross-sectional view of the liquid handling device of FIG. **14**;

FIG. **16** is a side view of the liquid handling device of FIG. **14**;

FIG. **17** is a side view of the liquid handling device of FIG. **14** coupled to a user reagent addition pump;

FIG. **18** is another side view of the liquid handling device of FIG. **14** coupled to the user reagent addition pump;

FIG. **19** is yet another side view of the liquid handling device of FIG. **14** coupled to the user reagent addition pump;

FIG. **20** is still another side view of the liquid handling device of FIG. **14** coupled to the user reagent addition pump;

FIG. **21** is a perspective view of the liquid handling device of FIG. **11** or **14** configured to mate with a communication module;

FIG. **22** is a perspective view of the liquid handling device of FIG. **11** or **14** configured to mate with a control module and communicate with a reservoir;

FIG. **23** is a perspective view of the liquid handling device of FIG. **22** configured to communicate with a gripper and/or a docking station;

FIG. **24** is a perspective view of yet another exemplary liquid handling device in accordance with the invention;

FIG. **25** is a perspective view of the liquid handling device of FIG. **24** with a cover removed;

FIG. **26** is perspective view of a bank of the liquid handling devices of FIG. **24**;

FIG. **27** is a right side view of the liquid handling device of FIG. **24**;

FIG. **28** is a left side view of the liquid handling device of FIG. **24**;

FIG. **29** is a front view of the liquid handling device of FIG. **24**;

FIG. **30** is a top view of the liquid handling device of FIG. **24**

FIG. **31** is a bottom view of the liquid handling device of FIG. **24**;

FIG. **32** is a perspective view of a further exemplary liquid handling device in accordance with the invention;

FIG. **33** is a right side view of the liquid handling device of FIG. **32**;

FIG. **34** is a left side view of the liquid handling device of FIG. **32**;

FIG. **35** is a front view of the liquid handling device of FIG. **32**;

FIG. **36** is a perspective view of the liquid handling device of FIG. **24** configured to mate with the communication module and communicate with a gripper and/or a docking station; and

FIG. **37** is a perspective view of the liquid handling device of FIG. **32** configured to mate with the communication module and communicate with a gripper and/or a docking station.

DETAILED DESCRIPTION

Because the invention was conceived and developed for use in handling liquids in analytical processes and especially bioanalytical processes such as introducing samples into LC systems, HPLC systems, etc., it will be herein described chiefly in this context. More particularly, the invention will be described in the context of a small form factor syringe pump system that can be configured as a plurality of devices intended to be utilized for aliquot operations in an automated liquid handling instrument. Typical containers for samples are micro-titration plates which typically have arrangements of wells on 9 mm centers (e.g. 96 well plates) and 4.5 mm centers (e.g. 384 well plates). The syringe pump system can be adapted to variable distance spanning motion technologies, which enables a plurality of tips to be distanced at centers greater than 9 mm for use with larger format sample collection media, e.g. vacutainers, sample vials or other larger diameter collection tubes. More generally, the principles of the invention in their broader aspects can be adapted to other types of systems.

Referring now in detail to the drawings and initially to FIGS. **1-4**, an exemplary embodiment of a liquid handling device **10** is shown. The liquid handling device generally comprises a housing **12** having opposite end portions **14** and **16**, herein referred to as first end portion **14** and second end portion **16**, forming a window where a plunger **18** and a barrel **20** are disposed. The first end portion **14** includes a recess **15** that opens to a rear of the second end portion **16**, the recess providing an access to at least one fastener **17** that secures the first end portion to the second end portion.

The barrel **20** is provided with an end connector **22** having a knurled surface **24** for hand screwing and a threaded portion **26** configured to be received in a threaded bore **28** in the housing **12**. The barrel receives the plunger **18** at an opposite end from the connector **22**, and the plunger **18** is pivotally connected to a carriage **30** by a pin **32**. The carriage **30** is configured to drive the plunger **18** in a bore of the barrel **20** for aspirating/dispensing fluid in/out of the barrel and from/to a fluid component (FIG. **7**, numeral **74**), such as a syringe needle. The syringe needle **74** is connected to a port **34** in the first end portion **14** and receives/delivers fluid from/to the barrel **20** via a passage **36** in the first end portion **14**.

As will be appreciated, the barrel **20** may be easily replaced by a barrel having the same or different diameter with a different volume, as shown in FIGS. **5** and **6**. The barrels may have, for example, a 5 miroliter to a 5 milliliter liquid volume and a 30 mm stroke length. The barrel **20** can be replaced by unscrewing the end connector **22** from the threaded bore **28**, and once the end connector is clear of the first end portion **14**, the barrel can be pivoted out of a plane

of the housing **12**. Then the barrel **20** can be removed and another barrel, such as barrel **40** or **42** can be coupled to the plunger **18** and secured to the housing **12** as described above. Alternatively, the plunger **18** and the barrel **20** may both be removed and replaced by another plunger and barrel having the same or different diameters, such as by plunger **44** and barrel **40** or by plunger **46** and barrel **42**, and the replacement plunger and barrel may be coupled to carriage **30** and secured to the housing **12** as described above.

Referring again to FIGS. **1-4**, the liquid handling device **10** includes in the second end portion **16** a drive mechanism **50** including a motive device, such as an electric rotary motor **52** connected by gears to a rotary-to-linear motion transfer device including a rotating drive screw **54** in mesh with the carriage **30**, preferably by means of a nut forming part of the carriage. The rotating drive screw **54** extends parallel to the movement direction of the plunger **18** and effects rotation of the plunger **18**. The drive screw **54** may be coplanar with the motor **52** and may be laterally offset and at least partially coextensive with the plunger **18**. The carriage **30** is constrained from rotation by a guide slot **56** in the housing **12** and the carriage **30** linearly drives the plunger **18**.

The liquid handling device **10** also includes in the second end portion **16** onboard electronics **60** for controlling the motor **52** and for communicating with an external component. The electronics may include a printed circuit board **62** and external connectors **64** and **66** preferably at a backside of the housing **12**. The connectors are provided to connect with an external component for receiving instructions for controlling the device, such as dispersing a certain amount of fluid, aspirating a certain amount of fluid, etc. The electronics may be onboard as shown, may be off-board as described below, or be both onboard and off-board. Moreover, the liquid handling device **10** may have wireless communications and therefore also include an onboard power source (not shown). Additionally or alternatively, the device **10** may be tethered to an off-board power source in any suitable manner.

As shown in FIG. **3**, the liquid handling device **10** has a thickness X. The thickness X correlates to the spacing between wells of a titration plate which the liquid handling device is intended to be used with. Conventional wells are on 9 mm and 4.5 mm centers, hence the thickness X may be no greater than 9 mm in one embodiment and 4.5 mm in another embodiment. This is shown for example in FIG. **7**, where a plurality of liquid handling devices are shown in side by side relation to one another, forming a bank of liquid handling devices. The bank of liquid handling devices is assembled at a center-to-center spacing of X.

Turning now in detail to the alternate embodiment shown in FIG. **7**, the plurality of liquid handling devices **10** have an electronic control module **68** removably mounted to the housings of the bank of devices **10**. The electronic control module **68** has a plurality of plug-together mating connectors **70**, **72** that mate with respective plug-together mating connectors **64**, **66** on the devices **10** for electrically connecting the electronic control module **68** to electrical circuitry in the respective housings **12**. The module **68** may be disposed in rear portions of the housings **12**.

It will be appreciated that when the electronic control module **68** is coupled to the devices **10**, the devices and control module still have a thickness less than or equal to nX, n being the number of devices **10** in the bank. The electronic control module **68** may be used in conjunction with or in place of the onboard electronics **60**, and may provide motor control, communications and power to the devices **10**. The control module may also include a power reduction circuit to reduce heat generation.

In another alternate embodiment shown in FIG. **8**, each device **10** may have a respective electronic control module **76** removably mounted to the housing **12**. The electronic control module **76** and the housing **12** have respective plug-together mating connectors **78**, **80** and **64**, **66** for electrically connecting the electronic control module to electrical circuitry in the housing. The module **76** may be disposed in a rear portion of the housing **12**.

The module **76** forms in essence part of the housing **12** but still is removable. It will be appreciated that when the electronic control module **76** is coupled to the device **10**, the device and control module still have a thickness less than or equal to x. The electronic control module **76** may be used in conjunction with or in place of the onboard electronics **60**, and may provide motor control, communications and power to the device **10**.

In still another alternate embodiment shown in FIG. **9**, each device **10** may have a respective onboard miniaturized electronic motor control **82** with a communications input. The motor control **82** is configured to mate with a communication module **84** via a connector **86**. The communication module **84** is a communication converter module to allow use of various standardized communications protocols, which may be wired or wireless protocols. The communication wires to each device **10** may be daisy chained to reduce wire count.

In a further embodiment shown in FIG. **10**, each device **10** may mate with the communication module **84** as described above, and may also have the capability to operate aspirate or dispense sequences while in a mobile gripper **88** and/or in a docking station **90**. The gripper **88** and docking station **90** have contacts **92** and **94** that mate with contacts **96** and **98** on the outside of the housing **12**. The contacts **92** and **94** are electrically isolated and provide power and communication signals to the device **10** via the contacts **96** and **98**. In this way, the device **10** may have pick-up and drop-off features incorporated therein.

Turning now to FIGS. **11-13**, another exemplary embodiment of a liquid handling device is shown as reference numeral **100**. This device **100** is the same as the device **10** shown in FIGS. **1-4** except as noted below, and accordingly, the same reference numerals are being used to describe like components. In this embodiment, the liquid handling device **100** is configured to function as a syringe pump, and accordingly includes a valve **102**, such as a solenoid valve, disposed in the first end portion **14**. The device **100** may include electronics **60** (or additional electronics) that can allow for pulse-width-modulated valve control for heat reduction and power conservation.

The valve **102** has a first port **104** connected to the syringe needle **74** via port **34**, a second port **106** connected to the barrel **20**, and a third port **108** connected to an inlet **110** that provides for connection of the liquid handling device **100** to a source of or reservoir for a liquid. The device **100** includes flow passages **112**, **114** and **116** that are connected to the ports **104**, **106** and **108** and the port **34**, barrel **20** and inlet **110**, respectively. As shown in FIG. **13**, the bore **28** to which the barrel is coupled is the common port C of the liquid handling device **100**, the port **34** is the normally closed port N/C and the inlet **110** is the normally open port N/O.

The valve **102** may be coplanar with the motor **52** and electronics **60** and may be longitudinally displaced from the motor and electronics. Accordingly, as discussed above, the valve **102**, together with the plunger **18**, motor **52** and

electronics **60** are assembled together in an imaginary envelope having a thickness no greater than X.

The liquid handling device **100** may also include a cutout **118** for the valve **102** in the first end portion **14**. The cutout provides an access to the at least one fastener **17** that secures the first end portion **14** to the second end portion **16**. After the first end portion has been secured to the second end portion, the valve **102** can be installed in the cutout and secured by suitable fasteners, such as fasteners **120** and **122**. The cutout **118** may then be closed on a side by a plate and on a back wall by a back plate, which may be secured in any suitable manner. Alternatively, the cutout **118** may be closed on the side and the back wall by a single plate.

Turning now to FIGS. **14-20**, another embodiment of the liquid handling device **100** is shown wherein the passages **112** and **114** are crossed. Accordingly, the first port **104** is connected to the barrel **20** and the second port **106** is connected to the syringe needle **74** via port **34**. This configuration is provided to allow for user reagent addition. As shown in FIG. **16**, the bore **28** to which the barrel is coupled is the normally closed port N/C, the port **34** is the common port C and the inlet **110** remains the normally open port N/O.

As shown in FIGS. **17-20**, a user reagent addition pump **124** is provided that is coupled by a supply line **126** to the inlet **110**. The supply line may run through a bore in the housing **12** or may run along an outside of the housing. As shown in FIG. **17**, the syringe **74** is filled with a sample from a sample container **128** and the sample is held in the barrel **20**. Then, as shown in FIG. **18**, reagents or diluents from the pump **124** are added into a different sample container **130**. Next, as shown in FIG. **19**, the sample is delivered from the barrel **20** through the syringe **74** and added to the reagents or diluents in sample container **130**. Then, as shown in FIG. **20**, the sample and reagents or diluents may optionally be mixed, for example by drawing the sample and reagents or diluents into the barrel **20** and then returning the mixture to the sample container **130**. The mixing step may be repeated if desired.

Turning now to FIG. **21**, another embodiment is shown wherein the liquid handling device **100** is mated with the communication module **84** as discussed above in FIG. **9**.

Turning now to FIG. **22**, still another embodiment is shown wherein the liquid handling device **100** is mated with the electronic control module **76** as discussed above in FIG. **8**. In this embodiment, however, the liquid handling device **100** also includes a detachable reservoir **132**. The inclusion of the reservoir can reduce fluidic complexity verses traditional liquid handling systems and can increase sample handling throughput. The reservoir may include a sample cartridge **134** that can have various volumes of various liquids. The cartridge **134** may be removable, reusable or disposable, and may be traceable, for example by barcode **136**. The cartridge **134** may be coupled to the inlet **110** via a supply line **138**.

Turning now to FIG. **23**, a further embodiment is shown that is similar to FIG. **22**, but which may also have the capability to operate aspirate or dispense sequences while in a mobile gripper **88** and/or in a docking station **90**, as described above in FIG. **10**.

Turning now to FIGS. **24-31**, another exemplary embodiment of a liquid handling device is shown as reference numeral **140**. This device **140** is similar to the device **10** shown in FIGS. **1-4** except as noted below, and accordingly, the same reference numerals are being used to describe like components.

The device **140** includes a barrel, plunger and drive assembly, which can be the same as that shown in FIGS. **1-4**, assembled together in an envelope having a front portion **142** including at least the barrel and plunger. The plunger **18** may be coupled to the carriage **30** as described above or may be coupled to the front portion in any other suitable manner.

The envelope includes a rear portion **144** including at least a portion of electronics **143**, which may be unitary with the housing **12**. As shown, the electronics **143** can include a motor control board **145** and an adaptor board **146** to provide motor control and communications. The motor control board **145** includes a connector **147** coupled to the adaptor board, such as by soldering pins of the connector to the board **146**. The electronics also include a connector **148**, which can provide a **6**-wire connection to a remote controller or network for receiving communications to and/or from the device and for providing power to the device. Alternatively, the electronics may be similar to the electronics discussed above in FIG. **1** or included in an electronic control module removably mounted to the housing **12** and contained within the envelope, as discussed above regarding FIG. **8**.

The rear portion **144** has a thickness greater than X but no greater than 2X, and the front portion has a thickness no greater than X and is laterally offset relative to a center plane of the envelope. The liquid handling device **140** can be assembled with another reversely oriented liquid handling device at a center-to-center spacing of X and a total combined width no greater than 2X. In this way, any suitable electronics having a thickness no greater than 2X may be used, such as commercially available electronics. For example, as shown in FIG. **26**, eight reversely oriented liquid handling devices **140** are provided. If the devices are to be wired, all wires associated with communication can be daisy chained to reduce the wire count.

Turning now to FIGS. **32-35**, another exemplary embodiment of a liquid handling device is shown as reference numeral **150**. This device **150** is the same as the device **130** shown in FIGS. **24-31** except the device **150** includes a valve **102**, a portion of which is shown through plate **152** suitably coupled to the housing **12**. The device **150** is also longer than the device **130** to provide space for the valve without increasing the thickness of the device **150**. The valve may be oriented as shown in FIGS. **11-13** or as shown in FIGS. **14-16**.

Turning now to FIG. **36**, another embodiment of the liquid handling device **140** is shown. The liquid handling device may mate with the communication module **84** as described above in FIG. **9**, and may operate while in a mobile gripper **88** and/or in a docking station **90** as described above in FIG. **10**.

Turning now to FIG. **37**, another embodiment of the liquid handing device **150** is shown. The liquid handling device may mate with the communication module **84** as described above in FIG. **9**, and may operate while in a mobile gripper **88** and/or in a docking station **90** as described above in FIG. **10**.

The above described liquid handling devices may be coupled to a suitably programmed computer and/or computer network for executing command signals for carrying out the required operations.

Although the invention has been shown and described with respect to a certain embodiment or embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of this specification and the annexed drawings. In particular regard to the various functions performed by the above described elements (components, assemblies, devices, compositions, etc.), the terms (including a reference to a "means") used to describe such elements are intended to

correspond, unless otherwise indicated, to any element which performs the specified function of the described element (i.e., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary embodiment or embodiments of the invention. In addition, while a particular feature of the invention may have been described above with respect to only one or more of several illustrated embodiments, such feature may be combined with one or more other features of the other embodiments, as may be desired and advantageous for any given or particular application.

What is claimed is:

1. A liquid handling device, in particular a syringe pump, for use in a liquid handling system including a plurality of the liquid handling devices assembled in side-by-side relationship at a center-to-center spacing of X, the device including:

a barrel,

a plunger movable parallel to a longitudinal axis in the barrel for dispensing or aspirating liquid from or into the barrel,

an electrically powered motive device for moving the plunger in the barrel for dispensing or aspirating liquid from or into the barrel, and

electronics for controlling the motive device and for communicating with an external component,

wherein the barrel, plunger, motive device and electronics are assembled together in an envelope having a front portion including at least the barrel and plunger, and a rear portion that is offset along a lateral axis from the front portion and that includes at least a portion of the electronics, wherein the lateral axis is perpendicular to the longitudinal axis,

wherein a center plane of the envelope extends along the longitudinal axis and extends parallel to the lateral axis, and

wherein the rear portion has a thickness greater than X but no greater than 2X, and the front portion has a thickness no greater than X and is offset relative to the center plane of the envelope along a normal axis that extends perpendicularly from the center plane, whereby the liquid handling device can be assembled with another reversely oriented liquid handling device at a center-to-center spacing of X and a total combined width no greater than 2X.

2. The liquid handling device according to claim **1**, wherein the barrel and motive device are disposed in a housing.

3. The liquid handing device according to claim **2**, wherein the electronics are disposed in an electronics module removably mounted to the housing and contained with said envelope.

4. The liquid handling device according to claim **3**, wherein the electronics module is disposed in the rear portion of the envelope.

5. The liquid handling device according to claim **3**, wherein the electronics module and housing have respective plug-together mating connectors for electrically connecting the electronics module to electrical circuitry in the housing.

6. The liquid handling device according to claim **2**, wherein the electronics include an onboard miniaturized electronic motor control with a communications input, the motor control being configured to mate with a communication module removably mounted to the housing and contained with said envelope.

7. The liquid handling device according to claim **6**, further including:

a gripper with contacts; and

a docking station with contacts;

wherein the housing includes contacts configured to mate with the contacts of the gripper and the contacts of the docking station, the gripper and/or the docking station allowing the device to operate aspirate or dispense sequences.

8. The liquid handling device according to claim **7**, wherein the contacts on the gripper and docking station are electrically isolated and configured to provide power and communication signals to the device.

9. The liquid handling device according to claim **1**, wherein the portion of the electronics is unitary with the housing.

10. A liquid handling system, including the liquid handling device according to claim **1**; and

the reversely oriented liquid handling device, wherein the liquid handling device and the reversely oriented liquid handling device include communication wires that are daisy chained to reduce wire count.

11. The liquid handling device according to claim **1**, further including a valve contained within the envelope, and wherein the electronics control operation of the valve.

12. The liquid handling device according to claim **11**, wherein the valve has a first port connected to a dispensing/aspirating lumen, in particular a syringe needle, a second port connected to the barrel, and a third port connected to an inlet that provides for connection of the liquid handling device to a source of or reservoir for a liquid.

13. The liquid handling device according to claim **11**, wherein the valve has a first port connected to the barrel, a second port connected to a dispensing/aspirating lumen, in particular a syringe needle, and a third port connected to an inlet that provides for connection of the liquid handling device to a source of or reservoir for a liquid.

14. The liquid handling device according to claim **13**, further including a user reagent addition pump that is coupled to the inlet by a supply line.

15. The liquid handling device according to claim **1**, wherein the barrel is removably mounted to a housing of the liquid handling device contained within the envelope.

16. A liquid handling system including 2, 3, 4 or more of the liquid handling devices of claim **1** assembled in side-by-side relationship at a center-to-center spacing of X.

17. The liquid handling device according to claim **1**, wherein X is 9 mm.

18. The liquid handling device according to claim **1**, wherein X is 4.5 mm.

19. A liquid handling device according to claim **1**, wherein the plunger is offset relative to the center plane of the envelope along the normal axis.

20. A liquid handling device according to claim **1**, wherein the rear portion has a thickness, parallel to the normal axis, greater than X but no greater than 2X, and the front portion has a thickness, parallel to the normal axis, no greater than X and is offset relative to the center plane of the envelope along the normal axis that extends perpendicularly from the center plane.

* * * * *